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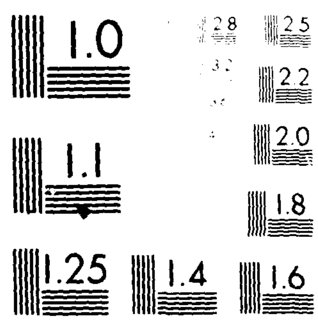

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FOREIGN TECHNOLOGY DIVISION

AN INFORMAL DISCUSSION CONCERNING GEOSYNCHRONOUS COMMUNICATION SATELLITES

by

Yi Yuanjian

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AN INFORMAL DISCUSSION CONCERNING GEOSYNCHRONOUS COMMUNICATION SATELLITES

Written by Yi Yuanjian. Illustrated by Zhang Zhenye.

For the last ten or so years, the international communications satellites put up have been getting larger. The largest to date has been the international communications satellite "V" which was placed in orbit on December 6 1980. (Refer to above illustration). (Translator's Note: No detail.)

These international communications satellites are all geosynchronous. Geosynchronous satellites orbit the Earth approximately 36,000 kilometers above the surface of the Earth at the Equator, travelling at a velocity of 3.067 kilometers per second. They complete one orbit of the Earth every twenty-four hours (to be precise, every twenty-four hours thirty-six minutes and four seconds), which is equal to the time it takes for the Earth to spin once on its own axis. It is for this reason that these satellites are called 'geosynchronous satellites'. As the angular velocity of the rotation of the Earth is identical to the angular velocity of the orbit of geosynchronous satellites, seen from the Earth, they always appear to be motionless. For example, suppose we are standing at point A on the Equator and we look up at a satellite in space at point A' directly above our heads, as a result of the Earth's rotation, we move to point B and then to point C etc. The satellite meanwhile moves successively from point A' to point B' and then to point C' etc. (See Figure 1). No matter to what point we move as a result of the rotation of the Earth, the satellite will always remain suspended in space above our heads as if it were absolutely motionless. It is for this reason that such satellites are also known as 'stationary satellites'.

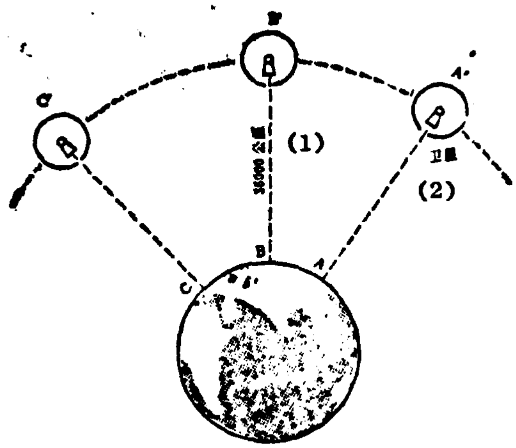

Fig. 1. Satellite seen from the Earth.
Key: (1) Kilometers; (2) Satellite.

Although the geosynchronous satellites in use now all have different apppearances, some are big and some are small, some are light and some are heavy, they are all made up of very many complex systems. The electronic instrumentation includes antenna systems, orbital maintenance and attitude control systems, telemetric and remote control systems, transmitter systems and power supply systems etc. These satellites have both directional and omnidirectional antennas. The directional antenna and the transmitter are designed to perform the communication function in conjunction with the ground installations; the power supply systems are designed to provide electrical power to all the other systems on the satellite; the omnidirectional antenna and other systems are used for computing the orbit of the satellite, for regulating the attitude of the satellite and for controlling the orbit of the satellite.

To ensure attitude stability of the satellite during its orbit, the method often used is that of spin-stabilization. This ensures that the satellite rotates around its own spin axis at a fixed velocity, maintaining attitude stability by means of the inertia generated by the spin. In order to keep the directional antenna pointing towards the center of the Earth or towards the area to be covered, the spin axis of the satellite and the equatorial plane must be kept at right angles, while the directional antenna must not be allowed to spin together with the body of the satellite. It must be allowed to spin only once every twenty-four hours. This is called spin reduction.

In order for the satellite to carry out its communication function, there must be established on the ground a ground communication facility which must be equipped with a large parabolic antenna (perhaps thirty meter diameter). (Figure2). The ground communication facility in conjunction with the satellite make up the communication circuit. When station X wants to make a telephone call to station Y, the voice signal from station X is modulated to become a radio frequency carrier wave (at, for example, 6000 megahertz), which is power amplified up to a very high level, generally several thousand watts, before being transmitted from the antenna aimed in the direction of the satellite. The satellite's directional antenna, which is kept pointing in the direction of the Earth by spin reduction, picks up the signal transmitted from the ground, and passes it to the transmitter. The transmitter amplifies the extremely attenuated signal before the directional antenna transmits the signal down again on a radio frequency carrier wave (at, for example, 4000 megahertz). Once the antenna at station Y has picked up the signal, it is amplified, demodulated and the voice signal from station X is separated out. In this way station Y can hear the voice from station X, To transmit the voice from station Y back to station X, a similar process is carried out.

Vital Equipment for Long-distance Communications

From a geosynchronous satellite suspended 36,000 kilometers up in space, more than two hundred million square kilometers of the Earth's surface can be seen. Because communications satellites use microwave frequency communication, and the frequency band is generally very wide, from several dozen megahertz to several hundred megahertz, from several thousand to as many as ten thousand two-way telephone channels can be handled at the same time. As long as they are within the 'line of sight' of the satellite, communications ground stations may be established anywhere they are required. Moreover, communications stations can be established on naval vessels at sea, on aircraft in the air, or on trains or vehicles on land. Using microwave relay communication, every station within a particular area may be linked up to long-distance and local telephone networks, enabling one satellite to handle the communication needs of an area on the surface of the Earth of close to ten thousand kilometer circumference.

Satellite communications have many advantages over short-wave and microwave relay communication systems, and, in the rapid progress made in long-distance communications over the last ten or so years, they have proved to be vital. Naturally, satellite communications have their disadvantages and shortcomings, requiring huge ground stations, high-power microwave transmitters and high-sensitivity receivers. At the same

time, communications satellites must operate under extremely adverse conditions, and when a component fails there is no one to rectify the problem. For this reason, their life is not long, generally only three to five years, or ten or so years at the most if the materials used are very good. Besides this, satellite launch technology is very complex, very difficult and very expensive.

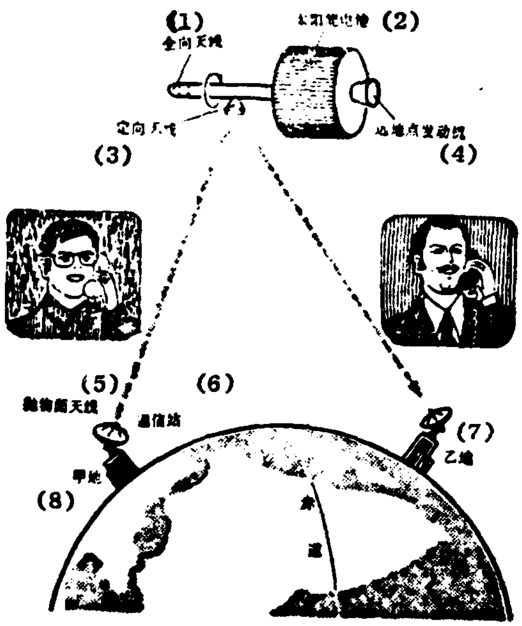

Fig. 2. Satellite communication circuit.
Key: (1) Omnidirectional antenna; (2) Solar panels; (3) Directional antenna; (4) Apogee engine; (5) Parabolic antenna; (6) Ground station; (7) Station Y; (8) Station X; (9) Equator.

The Launch Process for Geosynchronous Satellites

Geosynchronous satellites must orbit the Earth precisely 36,000 kilometers above the Equator - no more and no less - moving from West to East. We know that to avoid falling in to the Earth, an orbitting satellite must travel at a particular velocity. There is a relationship between the velocity required and the altitude of the satellite.

The higher the satellite, the lower the orbital velocity required. However, at an altitude of 36,000 kilometers, the orbital velocity of the satellite is only three kilometers a second. Yet to place a satellite in orbit at an altitude of 36,000 kilometers, requires much more energy than that required to maintain the orbital velocity. A very large three stage rocket is needed to place it in orbit. As each stage completes its burn, it must be jettisoned until the final stage is ignited. When the third stage rocket has performed its task, the satellite enters a large elliptical orbit. The apogee of this ellipse lies within the Earth's equatorial plane, at a distance of 36,000 kilometers from the surface of the Earth. We call this large elliptical orbit the 'transfer orbit'. (Figure 3). From launch until the satellite enters orbit, the rocket engines burn for half an hour. Controlling the satellites entry into a geosynchronous orbit and its exact positioning is the task of ground control. On the top section of the satellite is an apogee engine. When the satellite reaches the apogee of its elliptical orbit, this apogee engine is ignited and the satellite is propelled into a precise geosynchronous orbit. While the satellite orbits once every ten or so hours, ground control must carry out continuous capture, tracking, measurement and control. It takes ground control several days to measure the satellite's precise orbit and attitude. As the launching site of the satellite's carrier rocket is generally not on the Equator, more often than not there is an angle of inclination between the satellite's orbital plane and the Earth's equatorial plane. On the basis of the orbit, attitude and inclination measured, ground control must carry out remote control to adjust the satellite's attitude precisely to an attitude that will ensure that when the apogee engine does its burn, the velocity vector that is the resultant of the satellite's orbital velocity vector and the velocity vector of the apogee engine thrust is precisely that required to place the satellite in a geosynchronous orbit. To minimise the angle between the satellite's orbital plane and the Earth's equatorial plane, a launching site should be selected in the lowest possible latitudes.

Adjusting Position and Attitude

Once the satellite has entered a precisely geosynchronous orbit, its velocity, position and attitude will still not match the requirements completely. Therefore ground control will continue to compute the satellite position, and, on the basis of the data derived from these computations, progressively move the satellite into the precise geosynchronous orbit and the correct attitude. This process is usually known as 'fixing'. To complete the 'fixing' can take anything from ten to twenty days. Hence, the entire process of completing a satellite launch can take close to an entire month.

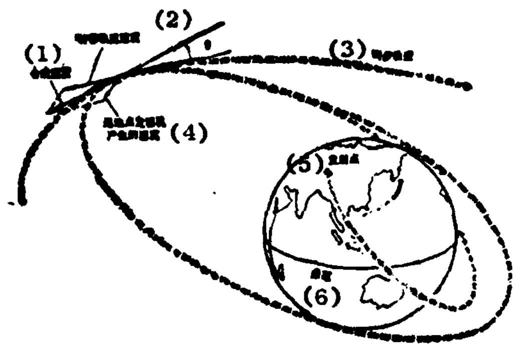

Fig. 3. Launching a geosynchronous communications satellite.
Key: (1) Resultant velocity; (2) Orbital velocity; (3) Geosynchronous orbit; (4) Velocity generated by apogee engine; (5) Launching site; (6) Equator.

Even when the satellite has been 'fixed", adjustment operations must still be carried out at regular intervals. The unevenness of the Earth, the gravitational attraction of the sun and the moon and other factors all exert an influence on the velocity of the satellite. If the satellite should drift from its predetermined position, adjustment must be carried out. In order to adjust the position and the attitude of the satellite, small lateral, longitudinal and tangential control jets are installed on the satellite. (Figure 4). These jets normally use hydrazine for fuel. If the satellite should deviate from the Earth's equatorial plane and drift to the North or to the South, ground control sends up a remote control command igniting the longitudinal control jets. Once the thrust of the longitudinal control jets has propelled the satellite back to its original position on the Earth's equatorial plane, the jets are shut down. If the satellite should drift off to the East or to the West, the remote control systems from ground control ignite the lateral control jets on the satellite. In this case, we must control precisely the exact instant that the control jets are ignited and the duration of the burn. This is because the body of the satellite is continuously spinning and so the direction in which the nozzles of the lateral control jets face is changing all the time. The required effect can be achieved only if the instant that the control jets are ignited and the duration of the burn are selected appropriately. If a change in the altitude of the satellite's orbit should occur, the lateral control jets can be used to make the necessary adjustment.

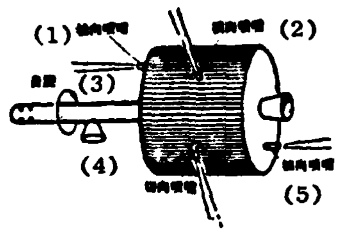

Fig. 4. Satellite orbit and attitude control systems.
Key: (1) Longitudinal control jet; (2) Lateral control jet; (3) Spin; (4) Tangential control jet; (5) Longitudinal control jet.

Due to external influences, the satellite's spin may tilt and the spin velocity may be reduced. This can cause the attitude of the satellite to change with the result that the directional antenna beam will deviate from the area to be covered, while, at the same time the solar panels installed on the outer shell of the satellite may not receive sufficient light to supply adequate power. For this reason, the attitude of the satellite must also be adjusted frequently. Sensors are installed on the satellite to detect heat, light, etc. Earth and solar sensors are instruments frequently used to measure the attitude of the satellite. The Earth sensor detects the infrared radiation from the Earth, while the solar sensor detects the light from the sun. These two sensors allow the attitude of the satellite to be determined with respect to the Earth and the sun. The satellite converts the output of the sensors to an electrical signal which is then amplified, modulated and transmitted to the ground. If ground control should discover that the attitude of the satellite is incorrect, the jets on the satellite can be controlled in order to carry out the necessary adjustments.

As the intensity of global communication increases, demands for more and more rapid communication are placed upon the system. In recent years, communications satellites have achieved rapid progress. We know that only one circular orbit, 36,000 kilometers above the surface of the Earth, on the Earth's equatorial plane, is possible for geosynchronous satellites. For this reason, the total number of satellites that can be accommodated is limited. To prevent interference, global agreements have been made to maintain a 3 - 5 degree separation between satellites using the same frequency. As a result of this agreement, 'full house' for geosynchronous satellites is 120. At the present time, the 'full house' level is getting close.

The End

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